CHEMICAL ENGINEERING TRANSACTIONS
VOL. 63, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jeng Shiun Lim, Wai Shin Ho, Jiří J. Klemeš

ISBN 978-88-95608-61-7; **ISSN** 2283-9216
DOI: 10.3303/CET1863049

The Implementation of Lean Construction Tools in Malaysia

Mohd Arif Marhani*, Nor Azmi Ahmad Bari, Khairani Ahmad, Aini Jaapar

Faculty of Architecture, Planning, and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
arif2713@salam.uitm.edu.my

Lean construction (LC) tools are proposed to resolve the issues of construction waste. LC is a continuous improvement in the construction processes that can manage the construction waste efficiently. The implementation of LC also will secure a better health and safety environment and accomplish in sustaining growth and profitability of an organisation. This study was conducted to investigate the availability of LC tools and its implications towards the quality of a construction product via the survey questionnaire. The questionnaire was sent to the contractors that register with the Construction Industry Development Board Malaysia (CIDB) underclass G7 categories in Malaysia. Based on the findings, the most LC tools implemented in the Malaysian construction industry are teamwork, daily hurdles meetings, and 5S. The implementation of LC tools can give a positive impact on the quality of the construction project. It shows that construction projects will produce a higher quality of the product by implementing LC. The findings outlined in this paper could be essential for the future framework of LC tools that can enhance the contractor's quality of a product towards sustainable low carbon emission development.

1. Introduction

Sustainable construction is a way forward for the construction industry to accomplish sustainability in development, while excessively taking environmental, socio-economic and cultural issues into consideration (Shafii et al., 2006). Nevertheless, many construction wastes are being produced due to the rapid development of the construction industry affected the environment solely (Fu and Teng, 2014). Equally, this problem occurred in the Malaysian construction industry due to the tremendous level of construction activity (Mah et al., 2017). Begum et al. (2010) reported industrial and construction industry generated 28.34 % of construction waste due to the current demand for building and infrastructure projects in Malaysia. Simultaneously, this issue overwhelmed the deficiency of overall worldwide resources, the economy, social and environment (Nagapan et al. 2012).

Construction waste refers to waste resulting from defective materials, leftover materials and wastage (Poon et al., 2004). There are seven categories of construction waste under the lean mechanism, which are the correction, over-processing, delay, inventory, conveyance, overproduction, and motion (Ogunbiyi et al., 2013). According to Abdul Rahman et al. (2012), waste can be generated during the designing goods and services processes, and mistake by human too. Construction waste gives an enormous impact on project costs and time of any of construction projects (Nagapan et al., 2012). The construction industry in Malaysia is urged to move from traditional wet construction method towards innovative construction techniques to overcome this issue.

LC is proposed resolving the issues of construction waste. Fundamentally, LC is a concurrent and continuous improvement in the construction processes that capable of in managing the construction waste (Marhani et al., 2012). LC is necessary for overcoming the issues and adequate in reducing the overall cost and duration of a construction project (Jaapar et al. 2015). The implementation of LC also promises a better quality of the construction project and will improve its performances too (Cho, 2011).

This article is intended to investigate the availability of LC tools and its implications towards the quality of a construction product in Malaysia. This paper also proposed to recommend a framework for LC tools that suitable for the Malaysian construction industry. This proposed framework will enhance the future of contractor's quality of a product towards sustainable low carbon emission development.

Please cite this article as: Mohd Arif Marhani, Nor Azmi Ahmad Bari, Khairani Ahmad, Aini Jaapar, 2018, The implementation of lean construction tools in malaysia, Chemical Engineering Transactions, 63, 289-294 DOI:10.3303/CET1863049

2. Lean construction

LC is an alternative mechanism that can be implemented in the Malaysian construction industry in settling the issues of construction waste. According to Yahya and Mohamad (2011), LC is about managing and improving the construction process by eliminating construction waste to meet the client's need. LC is also aiming for a better delivery process, concurrent and continuous improvement to the construction project throughout the life of the project. By implementing LC, an organisation will secure a better health and safety environment and accomplish in sustaining growth and profitability the organisation itself.

Table 1: LC tools in construction

LC tools	Coding	Authors
Standard Forms	LC1	Johansen and Walter (2007)
Management Contracts	LC2	Engineers Australia (2012)
Total quality management (TQM)	LC3	Engineers Australia (2012)
Concurrent Engineering	LC4	Engineers Australia (2012)
Value-based Management	LC5	Koskela (1992)
Increased Visualisation	LC6	Construction Industry Research and Information Association (2013)
Standardisation of Work	LC7	Engineers Australia (2012)
Last planner system (LPS)	LC8	Engineers Australia (2012)
Business Process Re-engineering	LC9	Koskela (1992)
Five Why's	LC10	Suresh et al. (2011)
Daily Huddle Meetings	LC11	Engineers Australia (2012)
First Run Studies	LC12	Building Research Establishment Ltd (2013)
Error Proofing (Poka-yoke)	LC13	Engineers Australia (2012)
Partnering	LC14	Johansen and Walter (2007)
Teamwork	LC15	Alinaitwe (2009)
Computer-aided Tools	LC16	Johansen and Walter (2007)
Supply Chain Management	LC17	Johansen and Walter (2007)
Just-In-Time	LC18	Engineers Australia (2012)
The 5S Process (Housekeeping system)	LC19	Construction Industry Research and Information Association (2013)
Industrialised Building System (IBS)	LC20	Suresh et al. (2011)

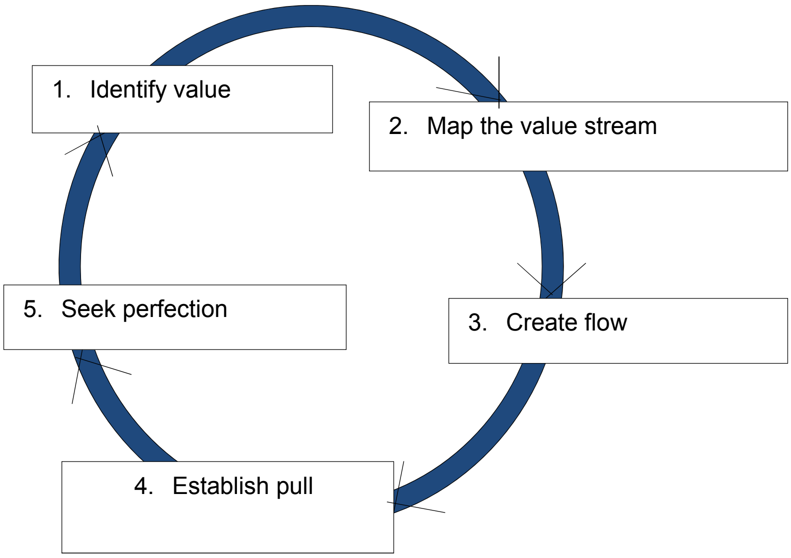

Figure 1: LC principles. Source: Marhani et al. (2012)

The literature showed there are implications to the construction project during the implementation of LC. According to Cho (2011), the implementation of LC promotes the construction project performances. These project performances can be measured in term of quality, cost and time (Construction Industry Research and Information Association, 2013). A construction project also can be measured through safety aspect, client's satisfaction, team member and environmental attributes (Cho, 2011).

This article only concentrates on the impact of LC mechanism on the quality of a construction project. According to Ogunbiyi et al. (2013), LC will provide a higher quality of product and the product itself is constructed as planned (Bashir, 2013). By implementing LC, it will increase the functionality of a project and reduce the numbers of defects (Aziz and Hafez, 2013). This LC mechanism needs an organisation to adopt appropriate or suitable LC tools to reap its benefits.

Previous researchers suggested specific tools or key concepts or techniques in their frameworks or guidelines. By using appropriate and proper tools (Suresh et al., 2011) to delivery process of a construction project, LC will provide more significant gains to the organisation. Thus, it shows the LC tools are present as the instrumental tool for the realisation of LC mechanism (Salem et al. 2005). There are twenty numbers of LC tools as per Table 1. An organisation should apply the application of these LC tools to gain the greater benefit of the mechanism. All these tools are using the LC principles in their activities. As per Figure 1, there are five LC principles, which are identify value, map the value stream, create flow, establish pull and seek perfection. These LC principles are incorporated and practised throughout the construction processes. Thus, the cooperation of team members and continuous improvement in enhancing the whole construction processes is needed during the forming of these LC principles.

3. Methodology

This paper concentrated on the availability of LC tools and its implications towards the quality of a construction product. A questionnaire survey is carried out to collect quantitative data, which included nine questions. This research method is also designed to identify the contractors who implemented the LC tools in their construction projects. Additionally, the study uses a 5-point Likert as a point of scales, which range from 1 = never use/strongly disagree to 5 = frequently use/strongly agree.

In this study, the unit of analysis used is the organisation. The data used is collected from contractors in Malaysia. The questionnaire was sent to randomly 392 contractors as well as a small sample of academics with interest in LC (5 for a pilot study and 387 for the primary study). Based on a stratified random sampling design, the target population for contractors was based on 6,000 companies that register with the CIDB underclass G7 (projects greater than Ringgit Malaysia 10 million) categories and were identified from the CIDB directory.

44 questionnaires were returned within seven months of being forwarded, making the complete response rate only 11.2 %. This response rate was finally achieved after several efforts were conducted regarding personal contacts and follow-up emails and calls. It is believed that the low rate of responses was due to the attitude, busy schedule and unwillingness of the respondents to participate in the survey. Although the norm response rate in the construction industry for postal questionnaires is around 20 – 30 % (Takim et al., 2004), the authors believed 11.2 % is uncommon but still acceptable. For instance, Dulaimi et al. (2003) received 5.91 %, Ofori et al. (2013) obtained 11.03 %, and Yunus (2012) received 14.9 % for their studies. The authors are confident with the respondents, who are taken from a high-quality group. Even if the survey response is not significant, it still produces substantial findings and outcomes to the study (Che Ibrahim, 2014).

4. Result and discussion

According to address the objectives of this study, this section presents an analysis of the data obtained through the quantitative research. A questionnaire survey conducted to ascertain the perspective of the LC tools to promote a better quality of construction project for the Malaysian construction industry. The quality that has been discussed here were either the LC tools provided a higher quality of a project, achieved the quality of a product as planned, increased the functionality of project and reduced nos. of defects. The findings will then be used to develop further and refine the LC tools framework.

4.1 Demographic study

The distribution or mixture of the professionals and organisations involved in this study is presented in Table 2. The largest proportion of the participants was meant for others, which were site quantity surveyors and contract officers (70.5 %) while 40.9 % of the respondents had more than ten years of experience in the industry. 32.9 % of them were involved in the housing project, and 35.2 % of the project sizes were worth more than 50 x 10^6 MYR. It can be concluded that most of the respondents were from practitioners' holdings managerial positions with more than 10 years' experience in the industry. Furthermore, most of the respondents were involved a lot in housing projects size more than 50 x 10^6 MYR. Their responses and thoughts are under a strong effect on the results of the study and established the reliability of the research as well.

Table 2: Distribution of the questionnaire survey

Designation					Experience (y)		
Managing Director	Project Manager	Site Supervisor	Others		Below 5	5 - 10	Above 10
9.1 %	15.9 %	4.5 %	70.5 %		38.6 %	20.5 %	40.9 %

Project type					Project size (10^6 MYR)				
Commercial	Industrial	Housing	Civil engineering	Others	< 2	2 - 5	5 - 10	10 - 50	> 50
27.4 %	6.8 %	32.9 %	24.7 %	8.2 %	11.1 %	11.1 %	22.2 %	20.4 %	35.2 %

4.2 The potential of LC tools

To identify the availability of LC tools in Malaysia, Table 3 indicates the list of LC tools. These tools were examined according to the construction stages (project definition, lean design, lean supply, lean assembly and use) by ranking them considered their mean values (μ) and standard deviation (σ_X).

Table 3: List of LC tools during construction stages

Project definition			Lean design			Lean supply			Lean assembly			Use		
LC tools	μ	σ_X	LC tools	μ	σ_X	LC tools	μ	σ_X	LC tools	μ	σ_X	LC tools	μ	σ_X
LC15	3.82	1.225	LC15	3.86	1.212	LC15	3.77	1.054	LC11	3.80	1.091	LC19	3.48	1.406
LC3	3.70	1.250	LC4	3.68	1.157	LC11	3.66	1.119	LC18	3.75	0.991	LC4	3.45	1.066
LC1	3.66	1.180	LC7	3.66	1.033	LC8	3.64	1.036	LC15	3.70	1.091	LC17	3.45	0.999
LC7	3.61	1.146	LC8	3.66	1.219	LC17	3.64	1.143	LC9	3.61	1.083	LC15	3.43	1.208
LC11	3.59	1.282	LC16	3.66	1.380	LC3	3.55	1.088	LC3	3.59	1.106	LC3	3.41	1.085
LC16	3.59	1.452	LC12	3.61	1.385	LC16	3.52	1.303	LC8	3.59	1.127	LC7	3.36	1.102
LC2	3.57	1.301	LC11	3.57	1.301	LC18	3.50	1.151	LC17	3.57	1.149	LC8	3.36	1.163
LC17	3.48	1.248	LC14	3.55	1.190	LC2	3.50	1.229	LC4	3.52	1.000	LC11	3.30	1.153
LC4	3.43	1.189	LC17	3.52	1.248	LC20	3.50	1.321	LC16	3.50	1.267	LC9	3.30	1.250
LC14	3.43	1.283	LC1	3.43	1.283	LC10	3.48	1.338	LC10	3.50	1.355	LC20	3.30	1.374
LC12	3.43	1.453	LC3	3.39	1.224	LC4	3.45	1.150	LC20	3.48	1.320	LC16	3.27	1.318
LC8	3.39	1.385	LC2	3.39	1.243	LC5	3.41	1.187	LC5	3.41	1.148	LC18	3.25	1.102
LC10	3.36	1.366	LC20	3.36	1.382	LC1	3.39	1.125	LC12	3.41	1.245	LC2	3.23	1.198
LC5	3.32	1.235	LC10	3.36	1.416	LC7	3.36	1.080	LC6	3.39	1.166	LC1	3.23	1.255
LC19	3.32	1.360	LC5	3.34	1.160	LC9	3.34	1.160	LC1	3.34	1.055	LC5	3.18	1.147
LC9	3.30	1.304	LC13	3.25	1.349	LC14	3.34	1.256	LC7	3.34	1.077	LC6	3.16	1.180
LC6	3.23	1.344	LC9	3.23	1.309	LC12	3.32	1.308	LC14	3.32	1.157	LC12	3.16	1.238
LC13	3.20	1.340	LC18	3.20	1.340	LC6	3.25	1.296	LC19	3.30	1.391	LC10	3.16	1.293
LC20	3.18	1.402	LC6	3.16	1.275	LC13	3.18	1.281	LC2	3.23	1.138	LC14	3.09	1.117
LC18	3.05	1.311	LC19	3.16	1.311	LC19	3.16	1.311	LC13	3.00	1.181	LC13	3.09	1.197

Teamwork is reported with the highest μ = 3.82, σ_X = 1.225 during the project definition, μ = 3.86, σ_X = 1.212 during the lean design and μ = 3.77, σ_X = 1.054 during the lean supply stage. Daily hurdles meetings are preferred during the lean assembly (highest μ = 3.80, σ_X = 1.091) while 5S is favoured during the use stage (highest μ = 3.48, σ_X = 1.406). It shows the contractors frequently used the twenty numbers of LC tools since all the LC tools received a μ greater than 3.00 throughout the construction processes. Teamwork, daily hurdles meetings, and 5S are the typical LC tools implemented by the contractors in Malaysia.

4.3 The implication of LC tools towards quality of a product

Table 4 indicates the implication of LC tools towards the quality of a product. According to the respondents, implementing teamwork in a construction project would provide a higher quality project (highest μ = 4.11, σ_X = 0.97) and increase the functionality of the project (highest μ = 3.95, σ_X = 0.861). By implementing TQM, it would reduce the numbers of defects (highest μ = 4.07, σ_X = 0.974) and achieve the quality of a product (highest μ = 3.95, σ_X = 0.939). It shows teamwork and TQM are the most strongly agree of LC tools that reflect the quality of a product in the construction project. By implementing these LC tools, it will provide a higher quality of a construction project.

Table 4: Implications of LC tools towards quality of a product

Providing a higher quality of project			Achieving quality of product as planned			Increasing the functionality of project			Reducing nos. of defects		
LC tools	μ	σ_X	LC tools	μ	σ_X	LC tools	μ	σ_X	LC tools	μ	σ_X
LC15	4.11	0.970	LC3	3.95	0.939	LC15	3.95	0.861	LC3	4.07	0.974
LC3	4.07	0.950	LC7	3.93	1.043	LC7	3.77	1.008	LC4	4.02	1.171
LC7	3.95	0.963	LC15	3.84	1.140	LC16	3.75	1.059	LC15	3.86	1.025
LC4	3.86	1.153	LC4	3.82	1.018	LC9	3.75	1.102	LC11	3.82	1.018
LC1	3.82	1.063	LC2	3.82	1.167	LC10	3.75	1.102	LC7	3.82	1.084
LC2	3.77	1.075	LC6	3.77	1.031	LC1	3.75	1.222	LC13	3.77	1.159
LC16	3.77	1.118	LC1	3.77	1.159	LC3	3.73	1.149	LC1	3.77	1.273
LC18	3.77	1.159	LC11	3.73	1.246	LC4	3.70	1.133	LC10	3.70	1.112
LC5	3.75	1.123	LC5	3.70	1.047	LC2	3.70	1.212	LC6	3.68	1.137
LC19	3.66	1.119	LC17	3.68	1.157	LC6	3.68	1.052	LC19	3.68	1.137
LC10	3.66	1.200	LC16	3.66	1.077	LC18	3.66	1.055	LC2	3.68	1.272
LC13	3.64	1.163	LC10	3.55	1.109	LC20	3.66	1.256	LC20	3.68	1.308
LC17	3.64	1.203	LC13	3.55	1.150	LC17	3.64	1.123	LC18	3.66	1.238
LC12	3.61	1.125	LC20	3.55	1.422	LC11	3.64	1.143	LC12	3.64	1.183
LC6	3.61	1.166	LC19	3.52	1.191	LC13	3.64	1.222	LC16	3.61	1.125
LC8	3.50	1.067	LC8	3.50	1.067	LC8	3.61	1.166	LC5	3.59	1.187
LC14	3.50	1.191	LC9	3.50	1.151	LC19	3.50	1.089	LC9	3.57	1.129
LC9	3.45	1.150	LC14	3.48	1.110	LC12	3.50	1.210	LC17	3.52	1.267
LC20	3.45	1.190	LC18	3.48	1.151	LC5	3.48	1.023	LC8	3.39	1.104
LC11	3.43	1.319	LC12	3.41	1.226	LC14	3.45	1.109	LC14	3.39	1.125

5. Conclusions

Based on the findings, it is discovered that most of LC practitioners in the Malaysian construction industry is knowledgeable regarding this mechanism. Most of them are manageable in dealing with its principles and tools. In the Malaysian construction industry, teamwork, daily hurdles meetings, and 5S are the most LC tools being implemented. Teamwork is very crucial when performing LC in a construction project. Cooperation and participation of all members in thinking, planning, decision-making, and action will smoothen the construction process. By implementing daily hurdles meetings, it will establish a platform for the team members to share their view in solving any problem during the lean assembly process. 5S will make a better and more comfortable working environment at the site. All these LC tools are best to be in the LC tools framework. TQM is advised to be on the list of LC tools framework. It will help any contractor to utilise its' human and material resources to achieve customers' satisfaction, profit, and growth of the contractor itself.

LC tools can give a positive impact on the quality of the construction project. It shows that construction projects will produce a higher quality of the product by implementing LC. Hence, implementation of LC tools is beneficial to the contractors and at the same time, it will enhance the client satisfaction.

The results could assist contractors intending to adopt LC in selecting the appropriate tools to address their needs. The findings reported in this paper could be essential for a future LC tools framework that can enhance the contractor's quality of a product towards sustainable low carbon emission development. Forthcoming research in a similar area will be done on case studies that have implemented LC mechanism by interviewing resource people on the site.

Acknowledgments

This research was supported by a grant from Fundamental Research Grant Scheme (FRGS/2/2014/SSI11/UiTM/0/02) funded by the Ministry of Education Malaysia and Universiti Teknologi MARA, Shah Alam, Selangor.

Reference

Abdul Rahman H., Wang C., Lim I., 2012, Waste processing framework for non-value-adding activities using lean construction, Journal of Frontiers in Construction Engineering, 1, 8-13.

Alinaitwe H., 2009, Prioritising lean construction barriers in Uganda's construction industry, Journal of Construction in Developing Countries, 14, 15-30.

Aziz R.F., Hafez S.M., 2013, Applying lean thinking in construction and performance improvement, Alexandria Engineering Journal, 52, 679-695.

Bashir A.M., 2013, A framework for utilising lean construction strategies to promote safety on construction sites, PhD Thesis, University of Wolverhampton, Wolverhampton, United Kingdom.

Begum R.A., Satari S.K., Pereira J.J., 2010, Waste generation and recycling: comparison of conventional and industrialized building systems, American Journal of Environmental Sciences, 6, 383–388.

Building Research Establishment Ltd, 2013, Construction Lean Improvement Programme (CLIP) <www.bre.co.uk> accessed 03.10.2013.

Che Ibrahim C.K.I., 2014, Development of an assessment tool for team integration in alliance projects, International Journal of Managing Projects in Business, 8, 813-827.

Cho S., 2011, The relation between lean construction and performance in the Korean construction industry, PhD Thesis, University of California, Berkeley, United States of America.

Construction Industry Research and Information Association, 2013, CIRIA Lean Construction guides <www.ciria.org> accessed 03.10.2013.

Dulaimi M.F., Ling F.Y., Bajracharya A., 2003, Organizational motivation and inter-organizational interaction in construction innovation in Singapore, Construction Management and Economics, 21, 307–318.

Engineers Australia, 2012, Recommended practices for the application of lean construction methods to building new Australian LNG capacity, Perth, WA.

Fu Q., Teng J., 2014, Analysis of the construction cost management based on the perspective of the construction waste recycling, International Conference on Management Science and Management Innovation (MSMI 2014), 14th-15th June, Changsha, China, 701-706.

Jaapar A., Marhani M.A., Ahmad Bari N.A., 2015, Green lean construction tools framework for Malaysian construction industry, Australian Journal of Basic and Applied Sciences, 9, 68–71.

Johansen E., Walter L., 2007, Lean construction: prospects for the German construction industry implementation of lean concepts in construction, Lean Construction Journal, 3, 19–32.

Koskela L., 1992, Application of the new production philosophy to construction <cife.stanford.edu/sites/default/files/TR072.pdf> accessed 02.10.2013.

Mah C.M., Fujiwara T., Ho C.S., 2017, Concrete waste management decision analysis based on life cycle assessment, Chemical Engineering Transactions, 56, 25–30.

Marhani M.A., Jaapar A., Ahmad Bari N.A., 2012, Lean construction: towards enhancing sustainable construction in Malaysia, Procedia - Social and Behavioral Sciences, 68, 87–98.

Nagapan S., Rahman I., Asmi A., 2012, Factors contributing to physical and non-physical waste generation in construction industry, International Journal of Advances in Applied Sciences, 1, 1-10.

Ofori G., Ai Lin E.T., Tjandra I.K., 2013, Effectiveness of Construction 21: enhancing professionalism in Singapore's construction industry, 19th International CIB World Building Congress, 5th-9th May, Queensland, Australia.

Ogunbiyi O., Oladapo A., Goulding J., 2013, A review of lean concept and its application to sustainable construction in the UK, International Journal of Sustainable Construction Engineering & Technology, 4, 82–92.

Poon C., Yu Ann, T., Jaillon L., 2004, Reducing building waste at construction sites in Hong Kong, Construction Management and Economics, 22, 461–470.

Salem O., Solomon J., Genaidy A., Luegering M., 2005, Site implementation and assessment of lean construction techniques, Lean Construction Journal, 2, 1–58.

Shafii F., Arman Ali Z., Othman M.Z., 2006, Achieving sustainable construction in the developing countries of Southeast Asia, The 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006), 5th-6th September 2006, Kuala Lumpur, Malaysia.

Suresh S., Bashir A., Olomolaiye P., 2011, A protocol for lean construction in developing countries, Contemporary Issues in Construction in Developing Countries. Taylor & Francis Ltd, 376–405.

Takim R., Akintoye A., Kelly J., 2004, Analysis of measures of construction project success in Malaysia, 20th Annual ARCOM Conference, 1st-3rd September, Edinburgh, UK, 1123–1133.

Yahya M.A., Mohamad M.I., 2011, Review on lean principles for rapid construction, Jurnal Teknologi (Sains & Kejuruteraan), 54, 1–11.

Yunus R., 2012, Decision making guidelines for sustainable construction of industrialised building systems, PhD Thesis, Queensland University of Technology, Queensland, Australia.